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Sharma

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(54) **MODULAR OFFLINE CHARGING SYSTEM THAT STORES ACCOUNTING DATA IN DATA SEGMENTS OF A STORAGE SYSTEM**

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H04M 15/00 (2006.01)
H04W 4/24 (2009.01)

(52) **U.S. Cl.**
CPC ***H04M 15/65*** (2013.01); ***H04W 4/24*** (2013.01)

(58) **Field of Classification Search**
CPC H04L 12/14; H04L 65/1016; H04L 12/1403; H04L 65/1006; H04L 65/1083; H04L 12/1471; H04L 12/1425; H04L 12/1435; H04L 12/1439; H04L 12/1457; H04L 12/1482; H04L 12/1407; H04L 12/189
USPC 455/406
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2009/0063315 A1* 3/2009 Cai G06Q 30/0284 705/32
2010/0005012 A1* 1/2010 Wahlberg G06Q 30/04 705/30
2012/0009895 A1* 1/2012 Kotalwar H04L 12/14 455/406
2012/0030077 A1 2/2012 Pei et al.

OTHER PUBLICATIONS

P. Calhoun et al., Diameter Base Protocol, Network Working Group, Request for Comments: 3588, The Internet Society, Sep. 2003.
V Fajardo et al., Diameter Base Protocol, Internet Engineering Task Force (IETF), Request for Comments: 6733, Oct. 2012.

* cited by examiner

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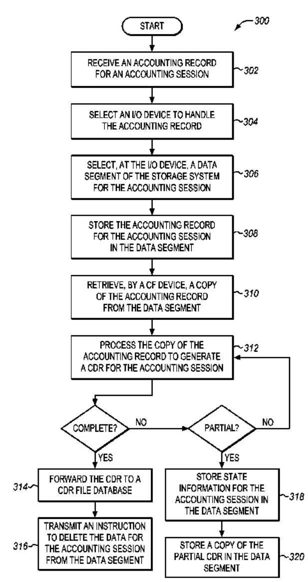
(57) **ABSTRACT**

Systems and methods for offline charging. An Offline Charging System (OFCS) includes a data storage system partitioned into a plurality of data segments, a plurality of Input/Output (I/O) devices configured to communicate with the data storage system, and a plurality of charging function devices configured to communicate with the data storage system. An I/O device receives an accounting record for an accounting session, selects a data segment of the data storage system for the accounting session, and stores the accounting record for the accounting session in the data segment. A charging function device retrieves a copy of the accounting record for the accounting session from the data segment, and processes the copy of the accounting record to generate a CDR for the accounting session.

20 Claims, 10 Drawing Sheets



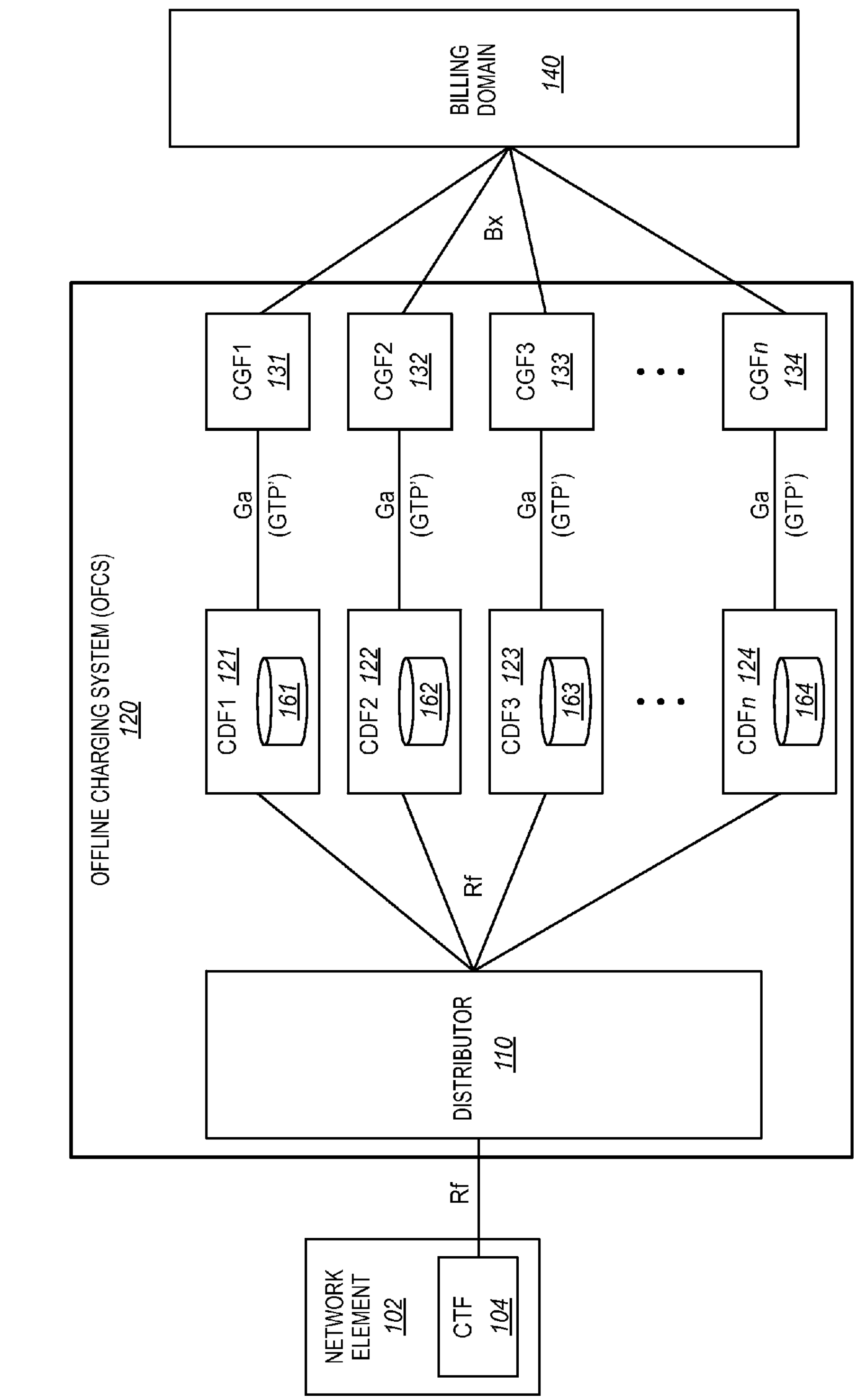


FIG. 1
PRIOR ART

FIG. 2

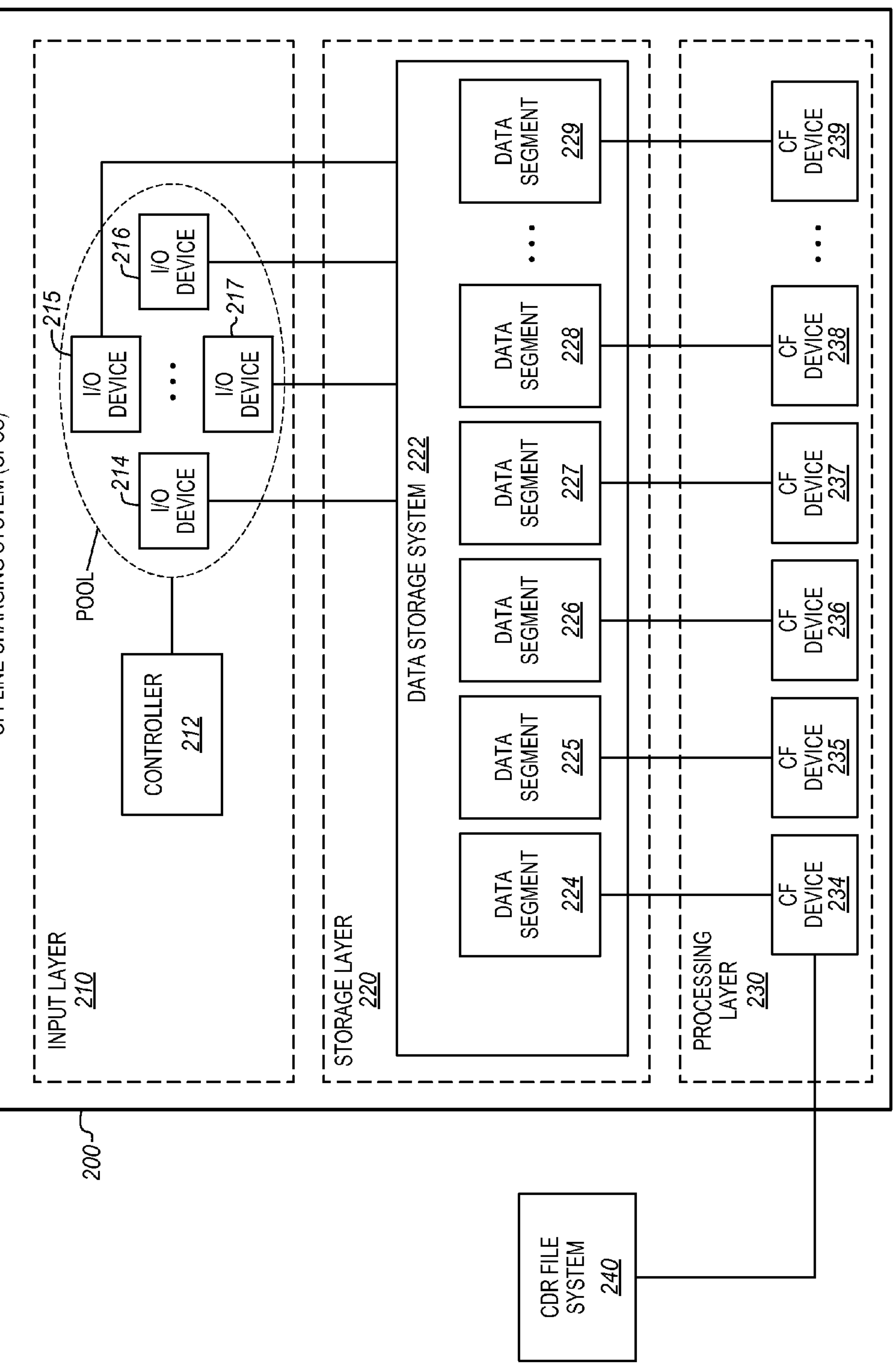
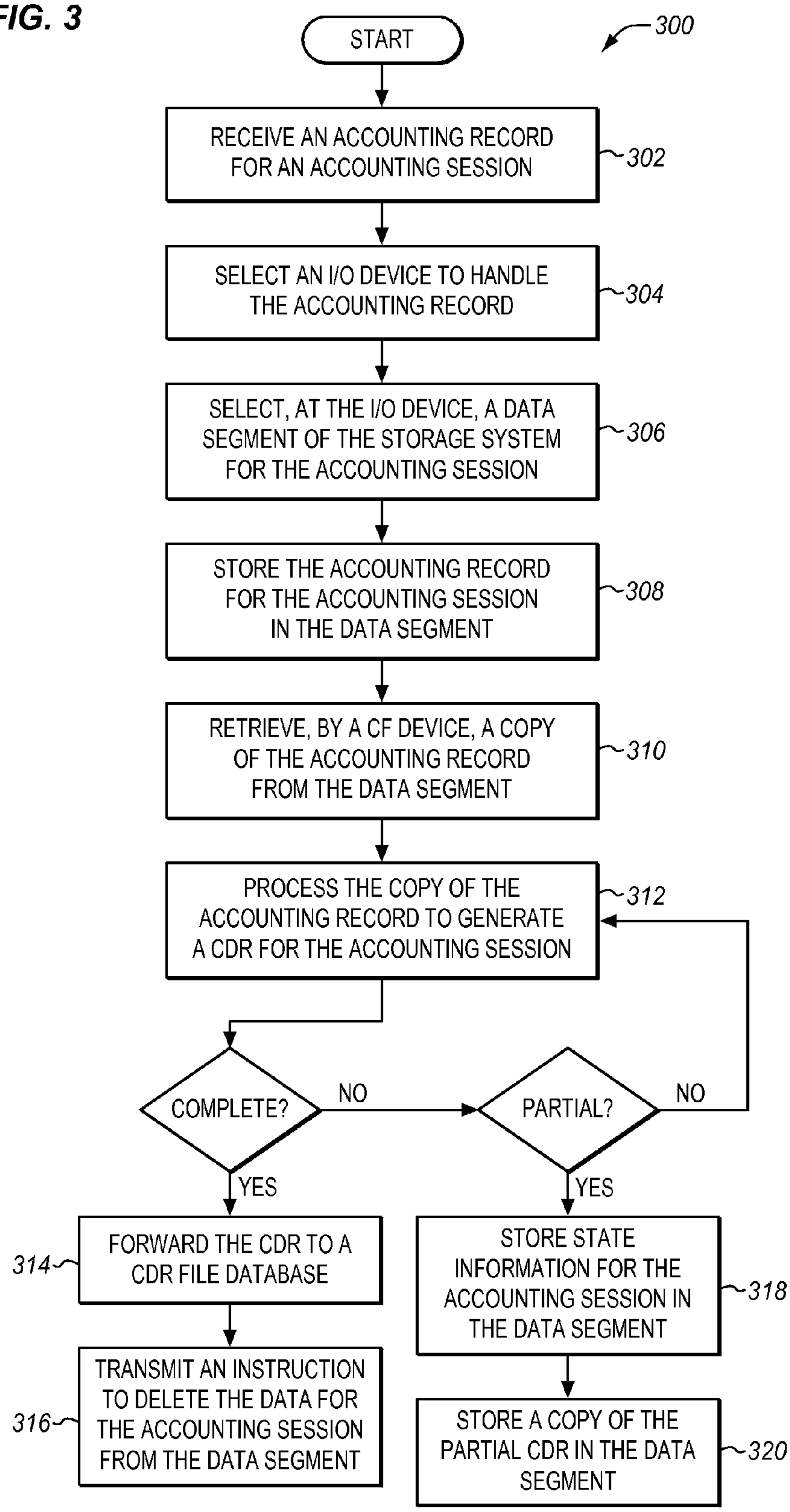

OFFLINE CHARGING SYSTEM (OFCS)
INPUT LAYER 210
CONTROLLER 212
POOL
I/O DEVICE 214
I/O DEVICE 215
I/O DEVICE 216
I/O DEVICE 217
STORAGE LAYER 220
DATA STORAGE SYSTEM 222
DATA SEGMENT 224
DATA SEGMENT 225
DATA SEGMENT 226
DATA SEGMENT 227
DATA SEGMENT 228
DATA SEGMENT 229
PROCESSING LAYER 230
CF DEVICE 234
CF DEVICE 235
CF DEVICE 236
CF DEVICE 237
CF DEVICE 238
CF DEVICE 239
200
CDR FILE SYSTEM 240

FIG. 3


300
START
RECEIVE AN ACCOUNTING RECORD FOR AN ACCOUNTING SESSION
302
SELECT AN I/O DEVICE TO HANDLE THE ACCOUNTING RECORD
304
SELECT, AT THE I/O DEVICE, A DATA SEGMENT OF THE STORAGE SYSTEM FOR THE ACCOUNTING SESSION
306
STORE THE ACCOUNTING RECORD FOR THE ACCOUNTING SESSION IN THE DATA SEGMENT
308
RETRIEVE, BY A CF DEVICE, A COPY OF THE ACCOUNTING RECORD FROM THE DATA SEGMENT
310
PROCESS THE COPY OF THE ACCOUNTING RECORD TO GENERATE A CDR FOR THE ACCOUNTING SESSION
312
COMPLETE?
NO
PARTIAL?
NO
YES
YES
FORWARD THE CDR TO A CDR FILE DATABASE
314
TRANSMIT AN INSTRUCTION TO DELETE THE DATA FOR THE ACCOUNTING SESSION FROM THE DATA SEGMENT
316
STORE STATE INFORMATION FOR THE ACCOUNTING SESSION IN THE DATA SEGMENT
318
STORE A COPY OF THE PARTIAL CDR IN THE DATA SEGMENT
320

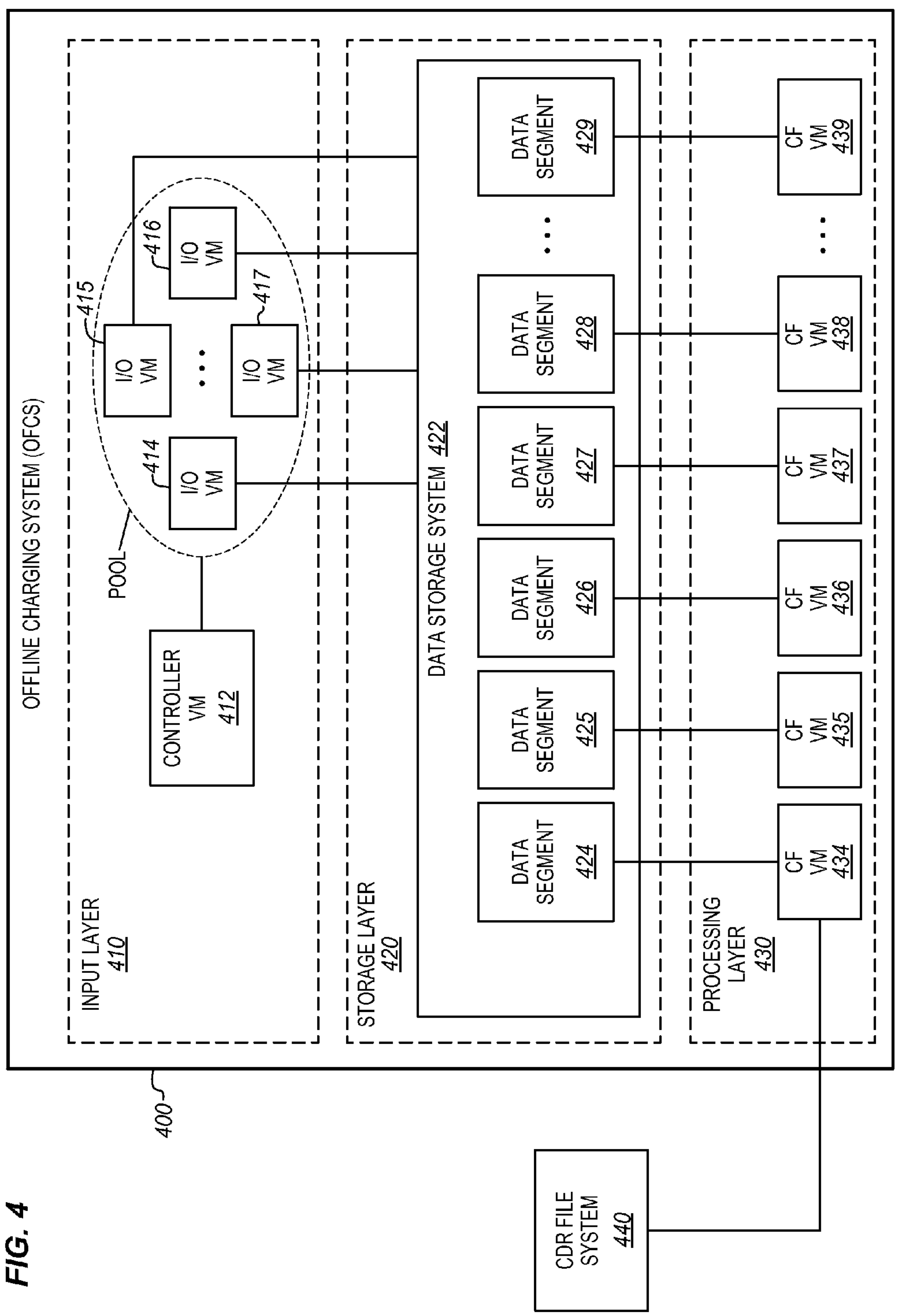

OFFLINE CHARGING SYSTEM (OFCS)
INPUT LAYER 410
CONTROLLER VM 412
POOL
I/O VM 414
I/O VM 415
I/O VM 416
I/O VM 417
STORAGE LAYER 420
DATA STORAGE SYSTEM 422
DATA SEGMENT 424
DATA SEGMENT 425
DATA SEGMENT 426
DATA SEGMENT 427
DATA SEGMENT 428
DATA SEGMENT 429
PROCESSING LAYER 430
CF VM 434
CF VM 435
CF VM 436
CF VM 437
CF VM 438
CF VM 439
400
CDR FILE SYSTEM 440

FIG. 4

FIG. 5

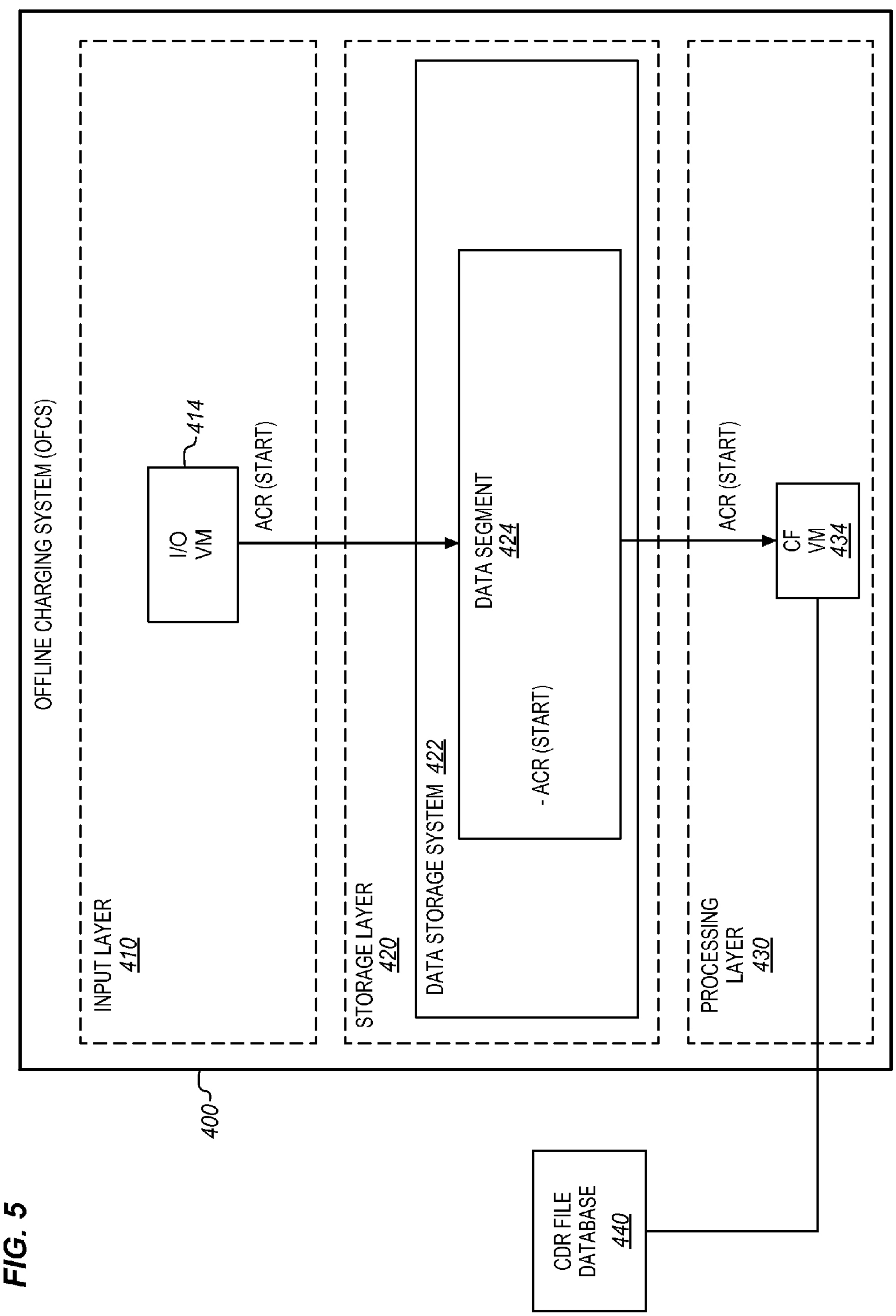
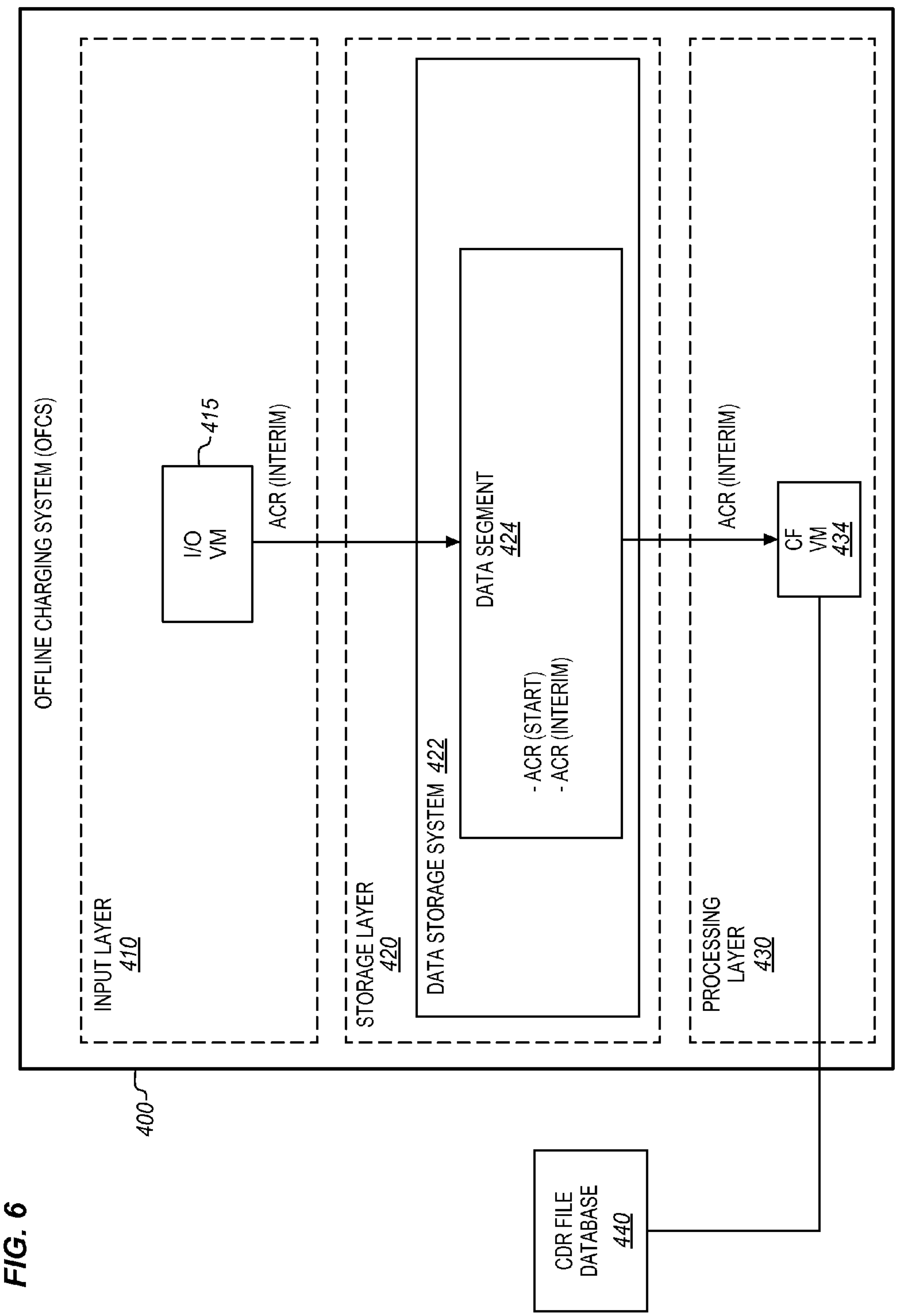

OFFLINE CHARGING SYSTEM (OFCS)
400
INPUT LAYER 410
I/O VM
414
ACR (START)
STORAGE LAYER 420
DATA STORAGE SYSTEM 422
DATA SEGMENT 424
- ACR (START)
PROCESSING LAYER 430
ACR (START)
CF VM 434
CDR FILE DATABASE 440

FIG. 6


OFFLINE CHARGING SYSTEM (OFCS)
400
INPUT LAYER
410
I/O
VM
415
ACR (INTERIM)
STORAGE LAYER
420
DATA STORAGE SYSTEM 422
DATA SEGMENT
424
- ACR (START)
- ACR (INTERIM)
ACR (INTERIM)
PROCESSING
LAYER
430
CF
VM
434
CDR FILE
DATABASE
440

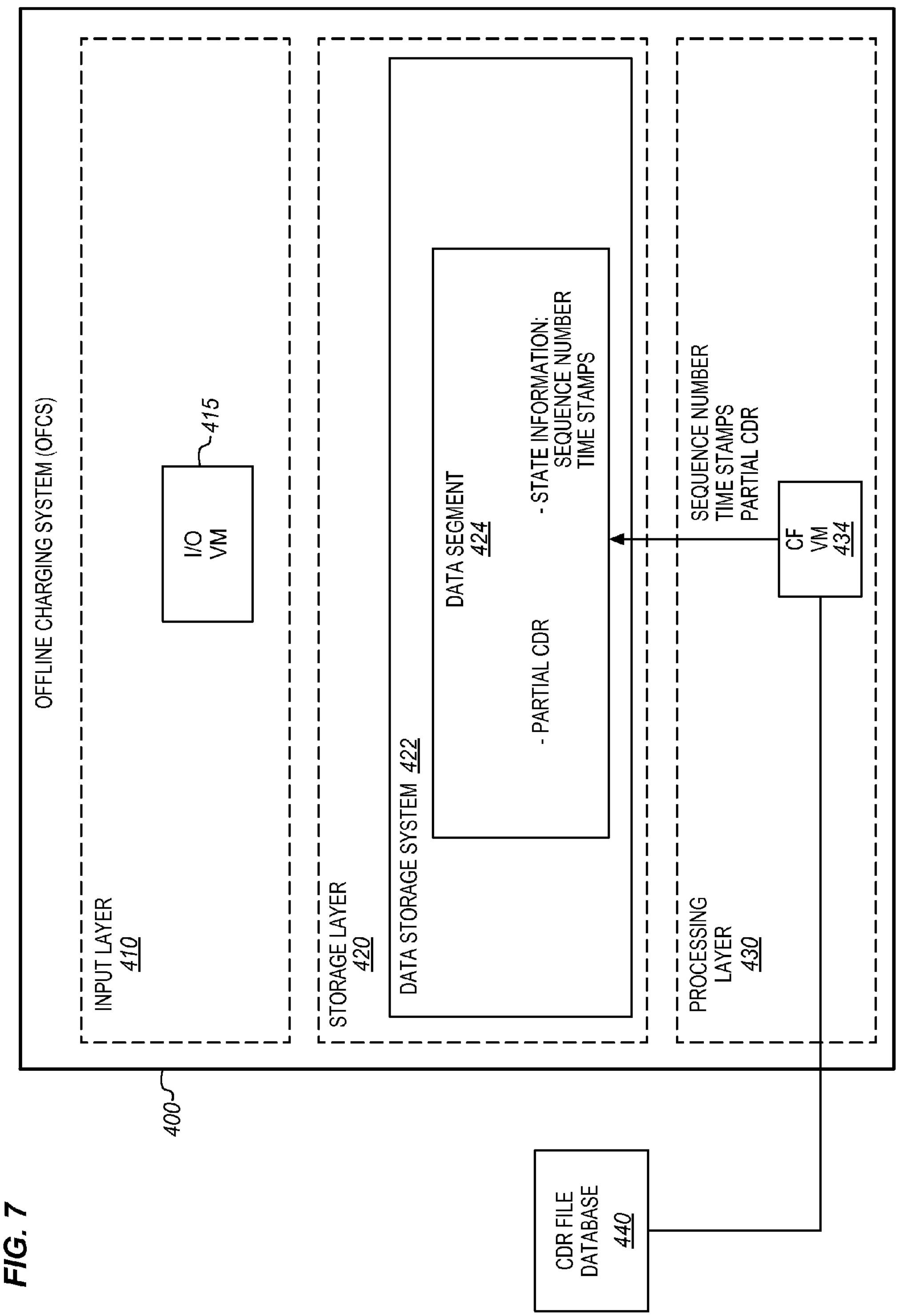
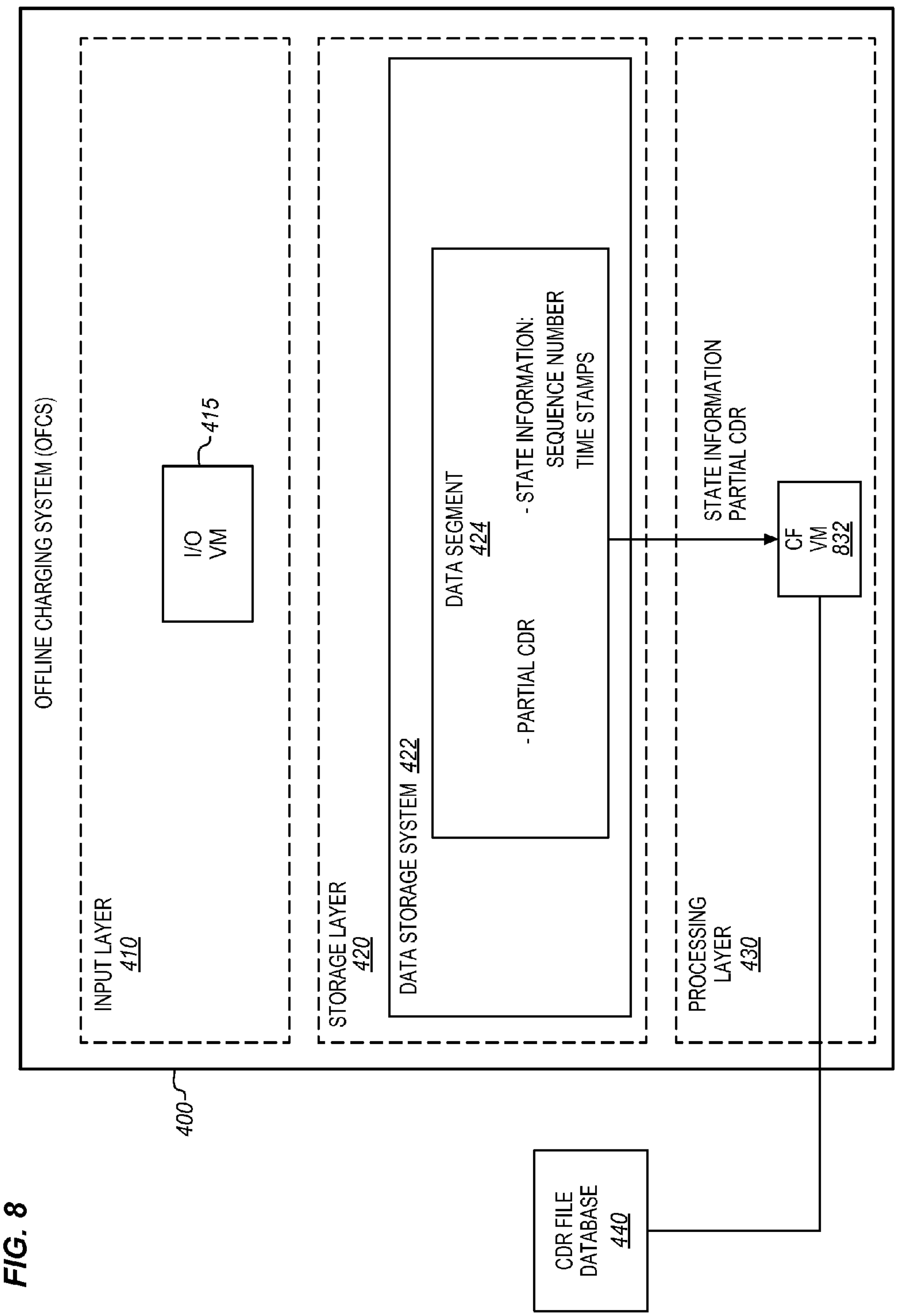

OFFLINE CHARGING SYSTEM (OFCS)
INPUT LAYER
410
I/O
VM
415
STORAGE LAYER
420
DATA STORAGE SYSTEM 422
DATA SEGMENT
424
- PARTIAL CDR
- STATE INFORMATION:
SEQUENCE NUMBER
TIME STAMPS
PROCESSING
LAYER
430
SEQUENCE NUMBER
TIME STAMPS
PARTIAL CDR
CF
VM
434
400
CDR FILE
DATABASE
440

FIG. 7

FIG. 8


OFFLINE CHARGING SYSTEM (OFCS)
INPUT LAYER 410
I/O VM
415
STORAGE LAYER 420
DATA STORAGE SYSTEM 422
DATA SEGMENT 424
- PARTIAL CDR
- STATE INFORMATION:
SEQUENCE NUMBER
TIME STAMPS
PROCESSING LAYER 430
STATE INFORMATION
PARTIAL CDR
CF VM 832
400
CDR FILE DATABASE 440

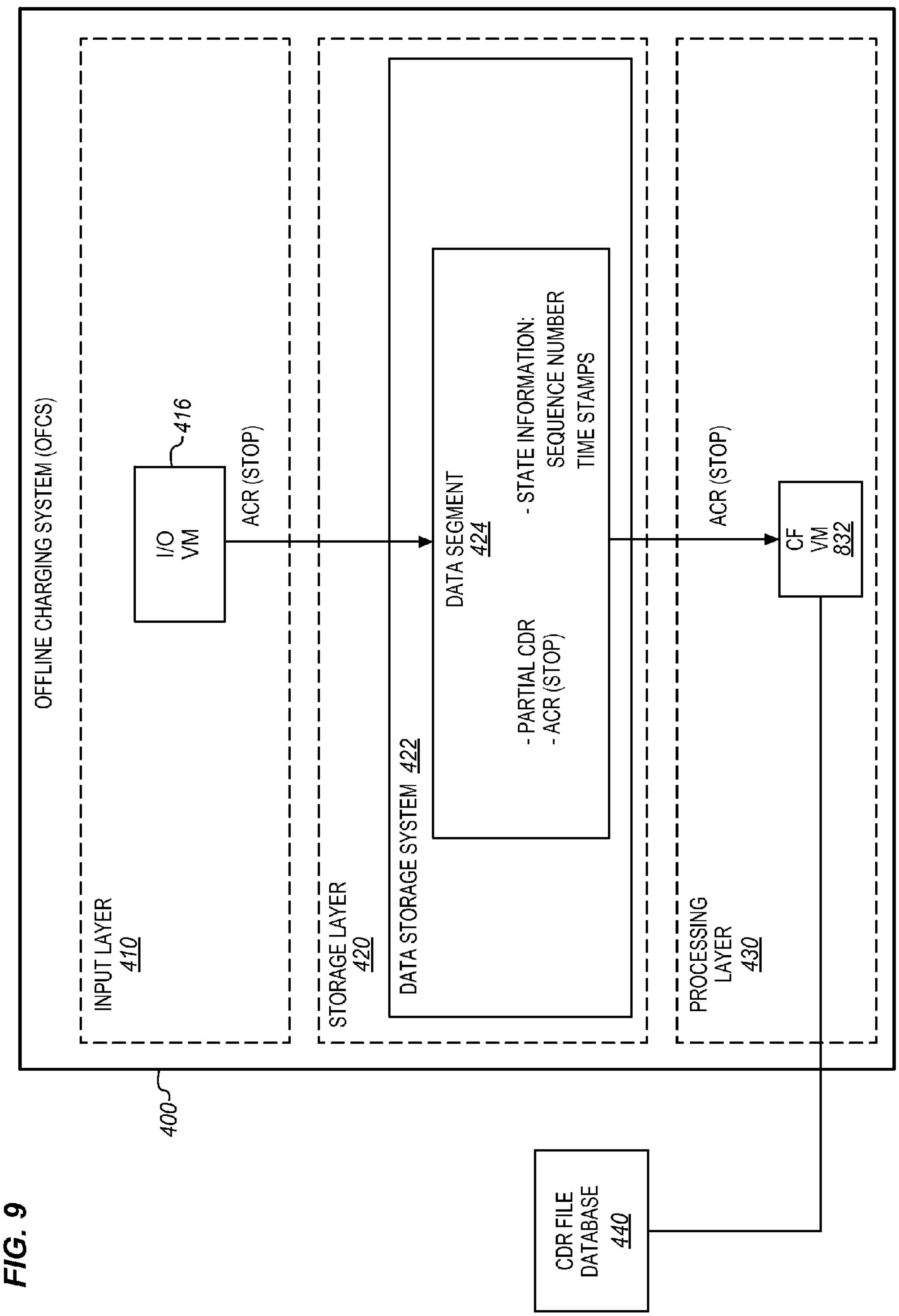

OFFLINE CHARGING SYSTEM (OFCS)
INPUT LAYER 410
I/O VM
416
ACR (STOP)
STORAGE LAYER 420
DATA STORAGE SYSTEM 422
DATA SEGMENT 424
- PARTIAL CDR
- ACR (STOP)
- STATE INFORMATION:
SEQUENCE NUMBER
TIME STAMPS
ACR (STOP)
PROCESSING LAYER 430
CF VM 832
400
CDR FILE DATABASE 440

FIG. 9

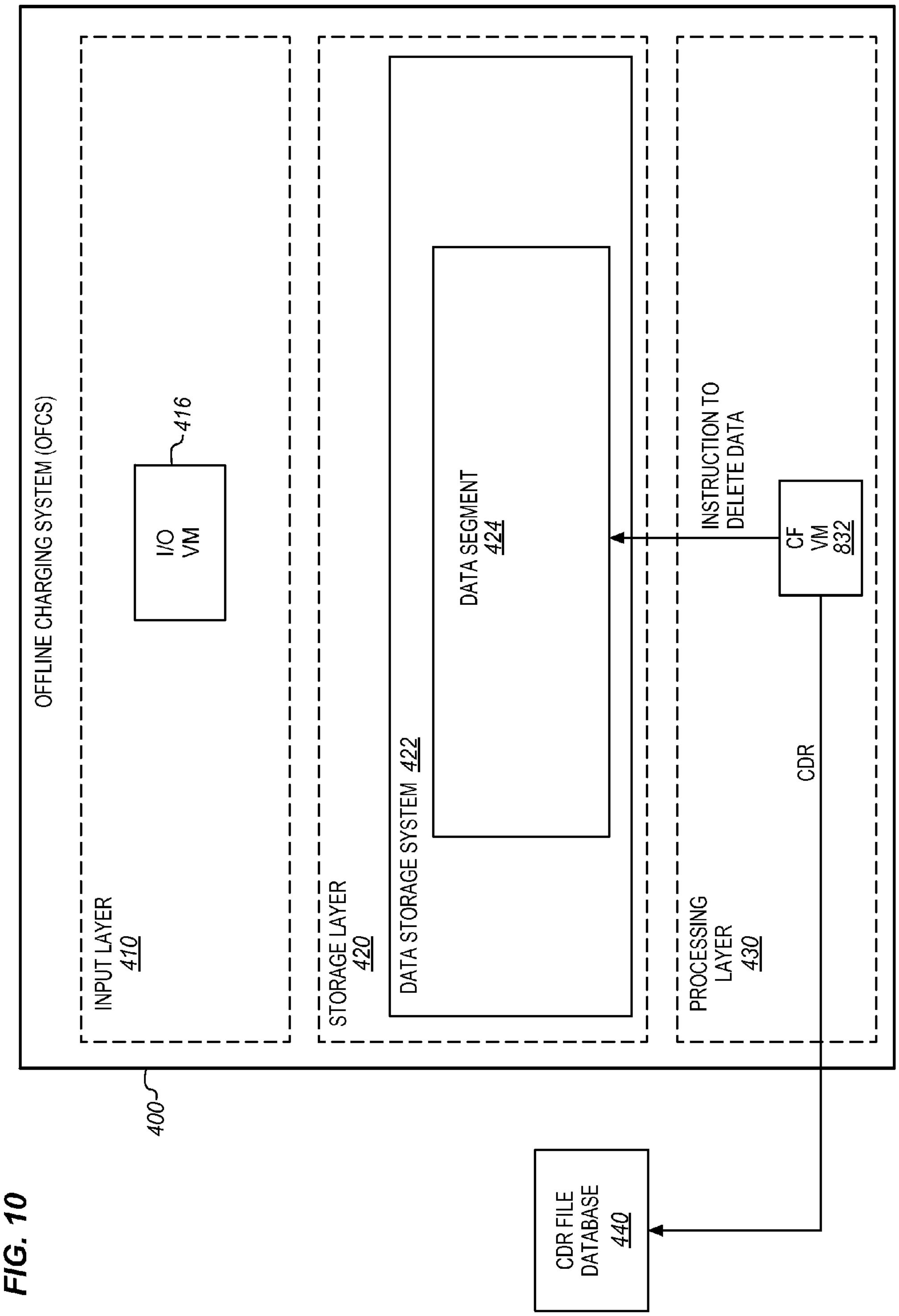

OFFLINE CHARGING SYSTEM (OFCS)
INPUT LAYER
410
I/O
VM
416
STORAGE LAYER
420
DATA STORAGE SYSTEM 422
DATA SEGMENT
424
INSTRUCTION TO
DELETE DATA
PROCESSING
LAYER
430
CF
VM
832
CDR
400
CDR FILE
DATABASE
440

FIG. 10

MODULAR OFFLINE CHARGING SYSTEM THAT STORES ACCOUNTING DATA IN DATA SEGMENTS OF A STORAGE SYSTEM

FIELD OF THE INVENTION

The invention is related to the field of communication systems and, in particular, to offline charging.

BACKGROUND

Service providers typically provide numerous voice and data services to end users (also referred to as subscribers). Examples of voice services are voice calls, call forwarding, call waiting, etc. Examples of data services are streaming audio, streaming video, Voice over Internet Protocol (VoIP), online gaming, and IP-TV. The data services are managed by a packet core network, which interfaces the end user with external Packet Data Networks (PDN), such as the Internet. Some examples of packet core networks are a General Packet Radio Service (GPRS) core network, an Evolved Packet Core (EPC) of a Long Term Evolution (LTE) network, etc. Mobile devices, such as cell phones, personal data assistants, smart phones, notebook computers, etc., may access the data services provided by the networks over an air interface with one or more base stations.

The service providers use offline and online charging functions to keep track of the resource usage incurred by each device accessing the various services. The 3GPP/3GPP2 standards groups have defined a set of specifications that may be used to implement online charging systems and offline charging systems in the various network domains (e.g., a circuit-switched domain, a packet-switched domain, and/or a wireless domain), IP multimedia subsystems (IMS), and emerging 3G/OMA application services.

According to 3GPP TS 32.240, offline charging is a process where charging information for network resource usage is collected concurrently with the resource usage. The charging information is passed through a chain of charging functions, which results in the generation of Charging Data Record (CDR) files that are transferred to the network operator's Billing Domain for subscriber billing and/or inter-operator accounting. To implement offline charging, a Charging Trigger Function (CTF) is implemented in a network element that provides a service. The CTF collects information pertaining to chargeable events, assembles this information into matching charging events, and sends the charging events to a Charging Data Function (CDF), which may be implemented in the network element or in the Offline Charging System (OFCS). The charging events may be provided by the CTF in an accounting request, such as a Diameter Accounting Request (ACR).

The CDF receives the charging events from one or more CTFs, and uses the information included in the charging events to construct CDRs. A CDR is a formatted collection of information about a chargeable event (e.g., time of call or session set-up, time of call or session tear-down, amount of data transferred, etc.) for use in billing and accounting. The CDF then sends the CDRs to a Charging Gateway Function (CGF) of the OFCS. The CGF acts as a gateway between the network and the billing domain. Therefore, the CGF collects CDRs from the CDF (and other CDFs), optionally correlates the CDRs and writes the CDRs into a CDR file, and makes the CDR file available to the billing domain.

A typical operator network will utilize multiple CDFs and CGFs to implement offline charging. Thus, a front-end device, such as a Diameter Routing Agent (DRA), is used in conjunction with the OFCS to distribute charging events from the CTFs to the CDFs. The front-end device typically uses a distribution algorithm to select a CDF for a particular session. For example, a distribution algorithm may process a session identifier from a Diameter ACR with a hashing function or another function to select a CDF. The front-end device then routes the Diameter ACR to the selected CDF. The CDF for a particular accounting session will store data for the ACR locally until the accounting session ends and one or more CDRs are generated. If the CDF happens to fail during the accounting session, the data for ACRs may be lost. Therefore, a network operator will not be able to charge for a complete service or session over the network.

SUMMARY

Embodiments described herein provide for improved offline charging that is less prone to lost revenue. An offline charging system (OFCS) as discussed herein uses a data storage system to store data for accounting sessions. Accounting data for individual accounting sessions is stored in data segments of the data storage system. A charging function device (e.g., CDF) accesses a data segment for an accounting session to obtain and process a copy of the accounting data. The accounting data is therefore kept in the data storage system, and may be processed by different charging function devices. In prior offline charging systems, a CDF received accounting data directly from a distributor, and stored the accounting data in local memory for the duration of the accounting session. If this CDF failed during the accounting session, then the accounting data would be lost and the network operator would lose revenue. In an OFCS as discussed herein, input devices store accounting data in the storage system, and charging function devices may access copies of the accounting data to generate CDRs. If a charging function device would happen to fail during an accounting session, another charging function device can access the accounting data for that accounting session in the storage system and generate the CDR(s) for the accounting session. Therefore, the OFCS provided herein is more robust, and less prone to failures that result in lost revenue for a network operator.

One embodiment is an OFCS that includes a data storage system partitioned into a plurality of data segments, a plurality of Input/Output (I/O) devices configured to communicate with the data storage system, and a plurality of charging function devices configured to communicate with the data storage system. An I/O device is configured to receive an accounting record for an accounting session, to select a data segment of the data storage system for the accounting session, and to store the accounting record for the accounting session in the data segment. A charging function device is configured to retrieve a copy of the accounting record for the accounting session from the data segment, and to process the copy of the accounting record to generate a CDR for the accounting session.

In another embodiment, the charging function device is configured to store state information for the accounting session in the data segment.

In another embodiment, the state information includes a sequence number for the partial CDR, and time stamps indicating a start time of the accounting session, and indicating a receipt time of the latest accounting record.

In another embodiment, the charging function device is configured to store a copy of the partial CDR in the data segment.

In another embodiment, the charging function device is configured to forward the CDR to a CDR file system when the CDR comprises a complete CDR.

In another embodiment, the charging function device is configured to transmit an instruction to the data storage system to delete data for the accounting session from the data segment.

In another embodiment, the charging function devices each implement a Charging Data Function (CDF) and a Charging Gateway Function (CGF).

In another embodiment, the data storage system comprises cloud storage.

In another embodiment, the I/O device is configured to select the data segment based on an IMS Charging Identifier (ICID) assigned to the accounting session.

In another embodiment, the I/O device is configured to select the data segment based on a session identifier assigned to the accounting session.

Another embodiment comprises a method for implementing an OFCS. The method includes receiving (by an I/O device) an accounting record for an accounting session, selecting a data segment of the data storage system for the accounting session, and storing the accounting record for the accounting session in the data segment. The method further includes retrieving (by a charging function device) a copy of the accounting record for the accounting session from the data segment, and processing the copy of the accounting record at the charging function device to generate a CDR for the accounting session.

The above summary provides a basic understanding of some aspects of the specification. This summary is not an extensive overview of the specification. It is intended to neither identify key or critical elements of the specification nor delineate any scope of the particular embodiments of the specification, or any scope of the claims. Its sole purpose is to present some concepts of the specification in a simplified form as a prelude to the more detailed description that is presented later.

DESCRIPTION OF THE DRAWINGS

Some embodiments of the invention are now described, by way of example only, and with reference to the accompanying drawings. The same reference number represents the same element or the same type of element on all drawings.

FIG. **1** illustrates an offline charging architecture in the prior art.

FIG. **2** illustrates an offline charging system in an exemplary embodiment.

FIG. **3** is a flow chart illustrating a method for offline charging in an exemplary embodiment.

FIG. **4** illustrates a virtualized OFCS in an exemplary embodiment.

FIG. **5** illustrates an I/O virtual machine (VM) storing an ACR(Start) in a data segment in an exemplary embodiment.

FIG. **6** illustrates an I/O VM storing an ACR(Interim) in a data segment in an exemplary embodiment.

FIG. **7** illustrates charging function VM storing the state information and partial CDR in a data segment in an exemplary embodiment.

FIG. **8** illustrates a charging function VM retrieving data for an accounting session from a data segment in an exemplary embodiment.

FIG. **9** illustrates an I/O VM storing an ACR(Interim) in a data segment in an exemplary embodiment.

FIG. **10** illustrates charging function VM sending a CDR to a CDR file system in an exemplary embodiment.

DESCRIPTION OF EMBODIMENTS

The figures and the following description illustrate specific exemplary embodiments. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the embodiments and are included within the scope of the embodiments. Furthermore, any examples described herein are intended to aid in understanding the principles of the embodiments, and are to be construed as being without limitation to such specifically recited examples and conditions. As a result, the inventive concept(s) is not limited to the specific embodiments or examples described below, but by the claims and their equivalents.

FIG. **1** illustrates an offline charging architecture **100** in the prior art. Architecture **100** includes a network element **102** that connects to an offline charging system (OFCS) **120** through a distributor **110**. Network element **102** includes a Charging Trigger Function (CTF) **104** that detects chargeable events for services provided by network element **102**, assembles information for the chargeable events into matching charging events, and sends the charging events to a Charging Data Function (CDF). In the case of network element **102**, CTF **104** may use a Diameter Rf interface. Therefore, CTF **104** assembles the charging information into accounting requests, such as a Diameter Rf Accounting Request (ACR). Although one CTF **104** is illustrated in FIG. **1**, there may be CTFs of many network elements in contact with distributor **110**.

OFCS **120** is an apparatus, a server, a device, or equipment configured to implement offline charging for sessions or services provided by a network. Offline charging can be of two types: session-based or event-based. In event-based charging, the CTF reports the usage or the service rendered where the service offering is rendered in a single operation, such as subscriber registration, re-registration, de-registration, etc. The CTF reports the usage in an ACR EVENT. Session-based charging is the process of reporting usage reports for a session, and uses the Start, Interim, and Stop accounting data. During a session, CTF **104** may transmit 0, 1, or multiple interim accounting requests depending on the proceeding of the session.

OFCS **120** includes multiple instances of a CDF (CDF**1**-CDFn) **121**-**124** and a CGF (CGF**1**-CGFn) **131**-**134**. A CDF comprises an element or module within OFCS **120** that receives charging events from CTFs within network elements, formats the charging events into CDRs, and sends the CDRs to a CGF. A CGF comprises an element or module within OFCS **120** that correlates CDRs for a session, and forwards a CDR file with the correlated CDRs to a billing domain **140**. Billing domain **140** is the part of the operator network that receives and processes CDR files for billing mediation and other billing applications (e.g., statistical applications). The CDFs in OFCS **120** may communicate with the CGFs over a Diameter Ga interface. In the case shown in FIG. **1**, GTP' may be used on the Ga interface to transport CDRs from the CDFs to the CGFs. While a 1:1 relationship is shown between the CDFs and CGFs in FIG. **1**, an N:1 relationship is also possible.

Distributor **110** is implemented between CTFs (e.g., CTF **104**) and the CDFs **121**-**124** in OFCS **120**. The purpose of distributor **110** is to distribute accounting requests (e.g., Diameter ACRs) from CTFs among the multiple CDFs

121-124 within OFCS 120. Distributor 110 may select CDFs for handling accounting requests based on a distribution algorithm, such as a "consistent hashing" algorithm.

Each CDF 121-124 includes a local memory 161-164, respectively, which is used to store accounting data when a CDF is handling an accounting session (which may also be referred to as a Diameter session). For example, when CDF 121 receives an accounting request, CDF 121 will process the data in the accounting request to format a CDR for the accounting session. CDF 121 stores data such as this for the accounting session in local memory 161.

One problem with the architecture of OFCS 120 is that data for an accounting session may be lost if CDF 121 fails during the accounting session. Because accounting data is stored locally in CDF 121, this data can be lost if CDF 121 fails. The network operator would therefore lose revenue. The following embodiments describe an enhanced offline charging architecture that is less prone to revenue loss.

FIG. 2 illustrates an offline charging system 200 in an exemplary embodiment. Offline charging system (OFCS) 200 is an apparatus, a server, a device, or equipment configured to implement offline charging for sessions or services provided by a network. In this embodiment, OFCS 200 includes an input layer 210, a storage layer 220, and a processing layer 230. The architecture of OFCS 200 is modularized so that input layer 210 is segregated from processing layer 230 by storage layer 220.

Input layer 210 represents the equipment, devices, functions, etc., that receive accounting records for accounting sessions. An accounting record is a collection of charging data for an accounting session, such as a Diameter Accounting Request (ACR) or a Charging Data Record (CDR). Input layer 210 may receive the accounting records from Charging Trigger Functions (CTFs) of network elements, or from an intervening distributor. In this embodiment, input layer 210 includes a controller 212 and a pool of input/output (I/O) devices 214-217. Controller 212 is configured to select an I/O device 214-217 from the available pool. An I/O device is configured to receive accounting records, and to store the accounting records in a particular location within storage layer 220. An instance of an I/O device 214-217 may comprise an Rf handler or a Ga handler. Depending on the type of accounting record that is received (e.g., ACR or CDR), controller 212 selects an I/O device 214-217 for Rf handling or an I/O device 214-217 for Ga handling from the available pool. Input layer 210 may be scalable, where additional I/O devices may be added if the demands exceed the load handling capacity.

Storage layer 220 represents the equipment, devices, functions, etc., that store data for accounting sessions. The data for an accounting session may be any data used to perform accounting functions within an offline charging system. For example, storage layer 220 may be used to store ACRs, CDRs, or state information for active accounting sessions. Storage layer 220 includes a data storage system 222, which comprises some type of shared memory or shared database that is accessible by input layer 210 and processing layer 230. For example, storage layer 220 may comprise cloud storage that is hosted on a remote platform that is accessible to elements of input layer 210 and processing layer 230 over a network, such as the internet.

Data storage system 222 is partitioned into a plurality of data segments 224-229. A data segment 224-229 may also be referred to herein as a shard, partition, bucket, etc. Each data segment 224-229 of data storage system 222 is used to store data for one or more accounting sessions. The configuration of data storage system 222 may vary as desired. In one embodiment, each data segment 224-229 may be set up in a master-slave replication mode (e.g., a 1+1 replication method, a 1+2 replica mode, etc.).

Processing layer 230 represents the equipment, devices, functions, etc., that process data for accounting sessions to generate CDRs that are passed to a billing domain. Processing layer 230 includes one or more charging function (CF) devices 234-239. A CF device implements charging functions for offline charging, which includes processing accounting requests (e.g., Diameter ACR) to generate a CDR for an accounting session. For example, each CF device 234-239 may provide an instance of a CDF and CGF, or an instance of a Charging Collector Function (CCF), that process accounting requests and generate CDRs. In this embodiment, each CF device 234-239 is assigned to a data segment 224-229 of data storage system 222. When a CF device 234-239 is assigned to a data segment 224-229, it means that the CF device 234-239 pulls data from that data segment for processing. A CF device 234-239 may be assigned to one data segment 224-229 as shown in FIG. 2, or multiple CF devices 234-239 may be assigned to one data segment. For example, N CF devices (e.g., one, two, four, eight, or some multiple of two) may be assigned to a single data segment. The number of CF devices assigned to a data segment may be uniform within processing layer 230.

FIG. 3 is a flow chart illustrating a method 300 for offline charging in an exemplary embodiment. The steps of method 300 will be described with reference to OFCS 200 in FIG. 2, but those skilled in the art will appreciate that method 300 may be performed in other systems. Also, the steps of the flow charts described herein are not all inclusive and may include other steps not shown, and the steps may be performed in an alternative order.

To begin, controller 212 in input layer 210 receives an accounting record for an accounting session, such as a Diameter ACR or a CDR (step 302). Controller 212 then selects an I/O device 214-217 to handle the accounting record (step 304) from the pool of available I/O devices. The selection of the I/O device 214-217 for an accounting record may be non-contextual, where consecutive accounting records from the same accounting session may be handled by different I/O devices 214-217. Controller 212 may use a round-robin algorithm to select an I/O device 214-217 from the available pool, or any other desired algorithm.

Assume for this embodiment that I/O device 214 is selected for the accounting record. When I/O device 214 receives the accounting record, it may parse the accounting record to ensure that it is syntactically and semantically correct. I/O device 214 selects a data segment 224-229 of data storage system 222 for the accounting session (step 306). In one embodiment, I/O device 214 may select the data segment 224-229 based on an IMS Charging Identifier (ICID) inserted in the accounting record. In another embodiment, I/O device 214 may select the data segment 224-229 based on a session identifier (e.g., Diameter Session Identifier (DSID)) inserted in the accounting record. The ICID and DSID are both generated in the network, and I/O device 214 may process a placement algorithm that hashes the ICID or DSID to select a specific data segment 224-229. The distribution of accounting sessions among the data segments 224-229 may be a fair distribution process.

After selecting a data segment (assume data segment 224), I/O device 214 stores the accounting record for the accounting session in the data segment 224 (step 308). Data segment 224 represents the storage location where all data for the accounting session is stored. Each I/O device or CF device will use the same distribution algorithm to find the location for the accounting session. Therefore, data segment **224** will store all the accounting records for the accounting session along with other data for the accounting session, such as partial CDRs, state information, etc.

CF device **234** is assigned to data segment **224** in this embodiment, and is tasked with handling accounting records that are stored in data segment **224**. When a new accounting record is stored in data segment **224**, CF device **234** retrieves a copy of the accounting record from the data segment **224** (step **310**). CF device **234** may periodically poll data segment **224** to determine when a new accounting record is saved. CF device **234** may also receive a message from I/O device **214** or controller **212** when a new accounting record is saved in data segment **224**. CF device **234** then processes the copy of the accounting record to generate a CDR for the accounting session (step **312**). CDF device **232** may retrieve and process other data from data segment **224** regarding the accounting session. The CDR generated by CF device **234** may comprise a complete CDR or partial CDR. For example, when CF device **234** processes an initial accounting record for an accounting session, it may open a CDR for the accounting session. There may be a trigger to close the CDR before the accounting session has ended, such as a CODEC being added or removed for a service, QoS being changed for a service, etc. A CDR that is closed before the accounting session has ended is referred to as a partial CDR, which provides information on part of an accounting session.

If CF device **234** generates a complete CDR for the accounting session, then it forwards the CDR to CDR file system **440** (step **314**). Generation of a complete CDR indicates that the accounting session has ended. Therefore, the data for the accounting session need not be stored in data segment **224** any longer. CF device **234** may also transmit an instruction to data storage system **222** to delete the data for the accounting session from data segment **224** (step **316**). This step is optional, as data storage system **222** may have its own algorithms or policies for deleting data from its data segments **224-229**.

CF device **234** also stores state information for the accounting session in data segment **224** (step **318**). The state information indicates what accounting has been performed for the accounting session up to this point in time. For example, the state information may include a sequence number for a partial CDR generated for the accounting session. If this partial CDR is the first partial CDR generated for the accounting session, then the state information may indicate that one partial CDR has been generated for the accounting session. If this partial CDR is the tenth partial CDR generated for the accounting session, then the state information may indicate that ten partial CDRs have been generated for the accounting session. The state information may also indicate time stamps for the accounting session. One time stamp may indicate the start time of the accounting session, and another time stamp may indicate the receipt time of the latest (or most recent) accounting record. CF device **234** may also store a copy of the partial CDR in data segment **224** (step **320**).

As is evident in the above embodiment, storage layer **220** acts as an intermediary between input layer **210** and processing layer **230**. I/O device **214** stores data for the accounting session in data segment **224**, and CF device **234** retrieves a copy of the data for the accounting session from data segment **224**. I/O device **214** does not need to send data for the accounting session directly to CF device **234**, and CF device **234** does not store the only copy of the data in a local memory. For instance, CF device **234** may take a snapshot of the accounting data in a data segment **224**, and work with this image in local memory. When processing of the records is finished, CF device **234** may transfer the processed snapshot back to data segment **224**. If CF device **234** happens to fail, another CF device may be assigned to data segment **224** to handle the accounting session. This CF device may retrieve a copy of accounting record(s), a partial CDR(s), and/or state information from data segment **224**, and process this data to provide the accounting functions for the accounting session going forward. Therefore, if there is an issue with the original CF device **234** during the processing of the data, no changes are effected in the data segment. Also, state information is processed and written back into data segment **224**. This state information includes the record sequence number for an accounting session, which identifies the sequence number of a partial CDR for the accounting session, and the timestamp(s) associated with the accounting record. Therefore, the next partial CDR may capture the start and end of the accounting session correctly.

Because the state information is maintained in the data segments **224-229**, it makes CF devices decoupled from the data that they process. This means that a substitution of one CF device with another CF device is a simple assignment task, such as by a scheduler. For example, another CF device (not shown in FIG. **2**) may be assigned to data segment **224** upon failure of CF device **234**. In this situation, the CF device is able to retrieve a copy of one or more accounting records for the accounting session from data segment **224**, and generate a CDR for the accounting session. Because the data for the accounting session is stored in a shared space, any CF device can be assigned to that data segment **224** and take over duties for the accounting session.

There may be situations where more than one CF device **234-239** is assigned to a data segment **224-229**. In these situations, a CF device **234-239** may work on sub-segments of a data segment. To ensure that CF devices do not process the same data within a data segment, an algorithm may be used to assign sub-segments to the CF devices. For example, the most significant hex digit of the ICID or session ID may be used to divide the data segment among multiple CF devices. The following illustrates an exemplary distribution of sub-segments among multiple CF devices:

CF Device Count	MS Hex Digit
1	All
2	CF device 1 owns 00h-7fh
	CF device 2 owns 80h-ffh
4	CF device 1 owns 00h-3fh
	CF device 2 owns 40h-7fh
	CF device 3 owns 80h-bfh
	CF device 4 owns c0h-ffh

EXAMPLE

An OFCS as described herein may be implemented as a physical network function (e.g., blade server) or as a virtual network function. FIG. **4** illustrates a virtualized OFCS **400** in an exemplary embodiment. OFCS **400** has a similar architecture as OFCS **200** with an input layer **410**, a storage layer **420**, and a processing layer **430**. The elements of input layer **410** comprise virtual machines (VM). A virtual machine is a software computer that runs an operating system and one or more applications, which imitates hardware. Specialized software called a "hypervisor" emulates a Central Processing Unit (CPU), memory, hard disk, network, and other hardware resources. Many virtual machines are able to share the physical resources of a host, and a pool of distributed hardware resources from different hardware platforms may be used to implement multiple virtual machines. In this embodiment, input layer **410** includes a controller VM **412** and a pool of I/O VMs **414-417**. Controller VM **412** is configured to select an I/O VM **414-417** from the available pool. An I/O VM is configured to receive accounting records, and to store the accounting records in a particular location within storage layer **420**.

Storage layer **420** includes a data storage system **422**, which comprises some type of shared memory or shared database that is accessible by input layer **410** and processing layer **430**. Data storage system **422** is partitioned into a plurality of data segments **424-429**.

The elements of processing layer **430** also comprise virtual machines (VM). Processing layer **430** includes one or more charging function (CF) VMs **434-439**. The CF VMs **434-439** implement charging functions for offline charging, which include handling accounting records. For example, each CF VM **434-439** may provide an instance of a CDF and CGF, or an instance of a CCF. In this embodiment, each CF VM **434-439** is assigned to one data segment **424-429** of data storage system **422**.

Although not shown in FIG. **4**, OFCS **400** may include an active pilot (or administrator) (VM) and a standby pilot VM.

Assume for this example that controller VM **412** receives a Diameter ACR(Start) for an accounting session (for session-based charging). Controller VM **412** selects an I/O VM **414-417** to handle the ACR(Start) from the pool of available I/O VMs. For example, controller VM **412** may use a round-robin algorithm to select an I/O VM **414-417** from the available pool. Assume for this example that I/O VM **414** is selected for the ACR(Start). When I/O VM **414** receives the ACR(Start), it selects a data segment **424-429** of data storage system **422** for the accounting session. For example, I/O VM **414** may select the data segment **424-429** by applying a hash function on the ICID or session ID associated with the accounting session. After selecting a data segment (assume data segment **424**), I/O VM **414** stores the ACR(Start) for the accounting session in the data segment **424**. FIG. **5** illustrates I/O VM **414** storing the ACR(Start) in data segment **424** in an exemplary embodiment. Data segment **424** represents the storage or memory location where all data for the accounting session is stored. Each I/O VM will use the same distribution algorithm to find this location for the accounting session.

CF VM **434** is assigned to data segment **424** in this example, and is tasked with handling ACRs and other accounting records that are stored in data segment **424**. When the ACR(Start) is stored in data segment **424**, CF VM **434** retrieves a copy of the ACR(Start) from the data segment **424** (see FIG. **5**), and processes the copy of the ACR(Start) for accounting purposes. CF VM **434** processes the ACR(Start) to open a CDR for the accounting session. CF VM **434** will continue to monitor data segment **424** for additional ACRs (Interim or Stop) for the accounting session.

Assume next that controller VM **412** receives a Diameter ACR(Interim) for the accounting session (see FIG. **4**). Controller VM **412** selects an I/O VM **414-417** to handle the ACR(Interim) from the pool of available I/O VMs. Assume for this example that I/O VM **415** is selected for the ACR(Interim). When I/O VM **415** receives the ACR(Interim), it selects the same data segment **424** of data storage system **422** for the accounting session (e.g., by hashing the ICID or session ID associated with the accounting session). I/O VM **415** then stores the ACR(Interim) for the accounting session in the data segment **424**. FIG. **6** illustrates I/O VM **415** storing the ACR(Interim) in data segment **424** in an exemplary embodiment.

When the ACR(Interim) is stored in data segment **424**, CF VM **434** retrieves a copy of the ACR(Interim) from the data segment **424** (see FIG. **6**). CF VM **434** then processes the copy of the ACR(Interim) to update the CDR for the accounting session.

Assume in this example that CF VM **434** closes the CDR to generate a partial CDR for the accounting session in response to the ACR(Interim). When CF VM **434** generates a partial CDR for the accounting session, it stores state information for the accounting session in data segment **424**. For example, CF VM **434** may store a sequence number for the partial CDR in data segment **424** and time stamps for the accounting session. One time stamp may indicate the start time of the accounting session, and the other time stamp may indicate the receipt time of the latest ACR. CF VM **434** may also store a copy of the partial CDR in data segment **424**. FIG. **7** illustrates CF VM **434** storing the state information and partial CDR in data segment **424** in an exemplary embodiment. CF VM **434** may also transmit an instruction to data storage system **422** to delete the ACR(Start) and ACR(Interim) from data segment **424** for the accounting session.

CF VM **434** may store or update state information in data segment **424** even when a partial CDR is not generated. For instance, when CF VM **434** retrieves an ACR(Interim) from data segment **434** that does not trigger generation of a partial CDR, it may update the state information in data segment **424** with a time stamp of the ACR(Interim).

If CF VM **434** happens to fail, another CF VM may be assigned to data segment **424** to handle the accounting session. For example, an orchestration layer may spin up a new CF VM to replace the CF VM **434** that failed. The new CF VM may retrieve a copy of the data stored in data segment **424** for the accounting session. FIG. **8** illustrates a CF VM retrieving data for the accounting session from data segment **424** in an exemplary embodiment. The new CF VM **832** retrieves a copy of the ACRs, the partial CDR, and/or the state information from data segment **424**, and processes this data to provide the accounting functions for the accounting session going forward.

Assume next that controller VM **412** receives a Diameter ACR(Stop) for the accounting session (see FIG. **4**). Controller VM **412** selects an I/O VM **414-417** to handle the ACR(Stop) from the pool of available I/O VMs. Assume for this example that I/O VM **416** is selected for the ACR(Stop). When I/O VM **416** receives the ACR(Stop), it selects the same data segment **424** of data storage system **422** for the accounting session (e.g., by hashing the ICID or session ID associated with the accounting session). I/O VM **416** then stores the ACR(Stop) for the accounting session in the data segment **424**. FIG. **9** illustrates I/O VM **416** storing the ACR(Stop) in data segment **424** in an exemplary embodiment.

When the ACR(Stop) is stored in data segment **424**, CF VM **832** retrieves a copy of the ACR(Stop) from the data segment **424**. Responsive to the ACR(Stop), CF VM **832** closes the present CDR for the accounting session, which is a complete CDR. CF VM **832** also aggregates the partial CDR with the complete CDR to generate an aggregated CDR for the accounting session, and forwards the aggregated CDR to CDR file system **440**. FIG. **10** illustrates CF VM **832** sending a CDR to CDR file database **440** in an exemplary embodiment. CF VM **832** may also transmit an instruction to data storage system **422** to delete the data for the accounting session from data segment **424**

Because data for the accounting session is stored in data storage system **422**, any CF VM can access the data and handle accounting duties for the accounting session. A network operator is less likely to lose revenue due to a failure of a CF VM with this OFCS architecture.

Any of the various elements or modules shown in the figures or described herein may be implemented as hardware, software, firmware, or some combination of these. For example, an element may be implemented as dedicated hardware. Dedicated hardware elements may be referred to as "processors", "controllers", or some similar terminology. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" or "controller" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal processor (DSP) hardware, a network processor, application specific integrated circuit (ASIC) or other circuitry, field programmable gate array (FPGA), read only memory (ROM) for storing software, random access memory (RAM), non-volatile storage, logic, or some other physical hardware component or module.

Also, an element may be implemented as instructions executable by a processor or a computer to perform the functions of the element. Some examples of instructions are software, program code, and firmware. The instructions are operational when executed by the processor to direct the processor to perform the functions of the element. The instructions may be stored on storage devices that are readable by the processor. Some examples of the storage devices are digital or solid-state memories, magnetic storage media such as a magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media.

Although specific embodiments were described herein, the scope of the disclosure is not limited to those specific embodiments. The scope of the disclosure is defined by the following claims and any equivalents thereof.

I claim:

1. An apparatus comprising:

an Offline Charging System (OFCS) comprising:

a data storage system partitioned into a plurality of data segments;

a plurality of Input/Output (I/O) devices configured to communicate with the data storage system; and

a plurality of charging function devices configured to communicate with the data storage system;

an I/O device is configured to receive an accounting record for an accounting session, to select a data segment of the data storage system for the accounting session, and to store the accounting record for the accounting session in the data segment;

a charging function device is configured to retrieve a copy of the accounting record for the accounting session from the data segment, and to process the copy of the accounting record to generate a Charging Data Record (CDR) for the accounting session.

2. The apparatus of claim **1** wherein:

the charging function device is configured to store state information for the accounting session in the data segment.

3. The apparatus of claim **2** wherein:

the CDR comprises a partial CDR; and

the state information includes:

a sequence number for the partial CDR; and

time stamps indicating a start time of the accounting session, and indicating a receipt time of the latest accounting record.

4. The apparatus of claim **2** wherein:

the CDR comprises a partial CDR; and

the charging function device is configured to store a copy of the partial CDR in the data segment.

5. The apparatus of claim **1** wherein:

the charging function device is configured to forward the CDR to a CDR file system when the CDR comprises a complete CDR.

6. The apparatus of claim **5** wherein:

the charging function device is configured to transmit an instruction to the data storage system to delete data for the accounting session from the data segment.

7. The apparatus of claim **1** wherein:

the charging function devices each implement a Charging Data Function (CDF) and a Charging Gateway Function (CGF).

8. The apparatus of claim **1** wherein:

the data storage system comprises cloud storage.

9. The apparatus of claim **1** wherein:

the I/O device is configured to select the data segment based on an IMS Charging Identifier (ICID) assigned to the accounting session.

10. The apparatus of claim **1** wherein:

the I/O device is configured to select the data segment based on a session identifier assigned to the accounting session.

11. A method for implementing an Offline Charging System (OFCS), wherein the OFCS includes a data storage system partitioned into a plurality of data segments, a plurality of Input/Output (I/O) devices configured to communicate with the data storage system, and a plurality of charging function devices configured to communicate with the data storage system, the method comprising:

receiving, by an I/O device, an accounting record for an accounting session;

selecting, by the I/O device, a data segment of the data storage system for the accounting session;

storing, by the I/O device, the accounting record for the accounting session in the data segment;

retrieving, by a charging function device, a copy of the accounting record for the accounting session from the data segment; and

processing the copy of the accounting record at the charging function device to generate a Charging Data Record (CDR) for the accounting session.

12. The method of claim **11** further comprising:

storing, by the charging function device, state information for the accounting session in the data segment.

13. The method of claim **12** wherein:

the CDR comprises a partial CDR; and

the state information includes:

a sequence number for the partial CDR; and

time stamps indicating a start time of the accounting session, and indicating a receipt time of the latest accounting record.

14. The method of claim **12** wherein the CDR comprises a partial CDR, the method further comprising:

storing, by the charging function device, a copy of the partial CDR in the data segment.

15. The method of claim **11** further comprising:

forwarding, by the charging function device, the CDR to a CDR file system when the CDR comprises a complete CDR.

16. The method of claim 15 further comprising:

transmitting an instruction from the charging function device to the data storage system to delete data for the accounting session from the data segment.

17. The method of claim 11 wherein:

the charging function devices each implement a Charging Data Function (CDF) and a Charging Gateway Function (CGF).

18. The method of claim 11 wherein:

the data storage system comprises cloud storage.

19. The method of claim 11 wherein selecting the data segment of the data storage system for the accounting session comprises:

selecting the data segment based on an IMS Charging Identifier (ICID) assigned to the accounting session.

20. The method of claim 11 wherein selecting the data segment of the data storage system for the accounting session comprises:

selecting the data segment based on a session identifier assigned to the accounting session.

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